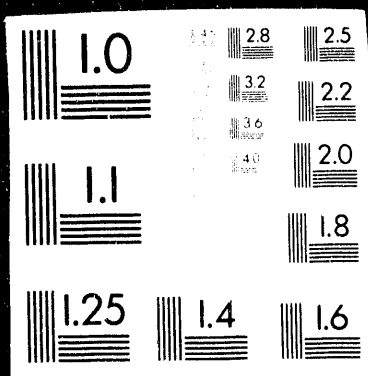


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NEW DIRECTIONS FOR THE TEAM WORKSHOPS

Larry R. Turner
Advanced Photon Source
Argonne National Laboratory
Argonne, Illinois 60439, USA

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INTRODUCTION

I consider it a great honor to be invited to speak at this, the first TEAM Workshop to take place in China. This is my first visit to China, and I am struck by the beauty of the country, by the kindness of the people I have met here, and by the rapid progress being made in every area.

The topic I have chosen for this talk is "New Directions for TEAM." But it has been said that in order to know where you are going, you must first know where you are and where you have been. So I will talk about the history and prehistory of the workshops and about some of their successes before I go on to my thoughts on new directions.

PREHISTORY OF TEAM

TEAM began from discussions in the US fusion power program in the spring of 1985. We were aware of the kinds of transient, 3-D eddy current computations that would be needed to design a tokamak fusion reactor, and aware that the codes existing then were far from adequate for that purpose. The workshops were suggested as a way to encourage code developers to upgrade their programs to perform the calculations we needed.

We decided to have an open meeting during COMPUMAG-Colorado (June 1983) to see if there was enough interest to do more planning for workshops. Forty persons from seven countries turned up on a rainy night for that meeting. There was consensus that the workshops were a good idea. In addition, the meeting suggested three features that were incorporated into the workshops: (1) Two-dimensional, as well as three-dimensional problems should be included. (2) The proceedings of the workshops should be published. (3) There should be regional workshops on different continents. From this third suggestion came the pattern of workshops that has been followed ever since: A two-year round of workshops consisting of one or two regional workshops each in Asia, Europe, and North America, followed by an international workshop held in conjunction with the next COMPUMAG conference.

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A planning meeting was held at Argonne National Laboratory 13-15 November 1986. Participants were Kent Davey from Georgia Institute of Technology, USA, Chris Emson from the Rutherford Appleton Laboratory, UK, Nathan Ida from the University of Akron, USA, Thanh Hua from the University of Washington, USA, Alain Nicolas from the Ecole Centrale de Lyon, France, David Rodger from Bath University, UK, Sandro Viviani from the University of Genoa, Italy, Ichiro Yanagisawa from Mitsubishi Atomic Power Industries, and Bob Lari, Rich Mattas, and Larry Turner from Argonne National Laboratory. In three hectic days we defined the goals and format, set the schedule, and chose six problems for the first round of workshops. At that first planning meeting, it was hoped that one of the first round workshops would take place in China, and we were disappointed that the leaders of the Chinese electromagnetic community whom we contacted felt that the state of eddy-current computation in China was not yet at a level to make a workshop useful.

HISTORY OF THE TEAM WORKSHOPS

ROUND 1

The first workshop of the first round was held at the Rutherford Appleton Laboratory, immediately following an eddy-current seminar. There was a good attendance. Several solutions were presented to three of the six problems, even though some of the participants had received the problems just two weeks before the workshop. The attendees were very patient with the disorderly nature of this first attempt to have a workshop. There was no attempt to prepare a summary of different solutions to the same problem, so we could achieve no conclusion about agreement among solutions.

The next workshop was held at Argonne National Lab. Solutions were presented for four of the problems. Here for the first time a summary and comparison were prepared by the presenters for each problem.

The Tokyo workshop was a major step forward. Solutions were presented for all six problems. Presenters submitted their results in advance, and Akihisa Kameari of Mitsubishi Atomic Power Industries prepared graphs summarizing the results. There were more than 50 participants.

I did not attend the Lyon workshop, which was preceded by a one-day seminar on 3-D pre- and post-processing. Ten participants attended the Georgia Tech workshop in Atlanta. The workshop concentrated on Problem 6; six presentations described 20 solutions. Comparing the sparse

attendance at the Argonne and Georgia Tech workshops with the large attendance at the Rutherford and Tokyo workshops demonstrated the value of holding the workshops in conjunction with other conferences or seminars.

At the international workshop which immediately preceded COMPUMAG-Graz, there was strong support for continuing the workshops without much change of format. Six more problems were adopted, and four more regional workshops planned. Also, the decision was made to close problems for which solutions were adequate and well understood. Before the workshop at Graz, solutions for each problem were collected by a chairman for that problem. The chairman presented a summary at the workshop and also wrote it up as a paper for a special issue of the journal COMPEL.

ROUND 2

The first workshop of the second round was held in Vancouver, British Columbia, immediately after the joint Intermag/MMM Conference there. Solutions were presented for most of the active problems. Problem 12, the cantilevered beam, had been considered too difficult by many when it was proposed, but at the Vancouver workshop, Prof. Morisue of Nagoya University presented a solution he obtained on his PC.

At the second workshop, held in Capri together with a seminar on industrial applications of eddy current computation, there was a suggestion that the TEAM workshops be broadened to include topics other than eddy current computation, in particular that magnetostatics be included. This suggestion was further discussed at the third and fourth workshops, at Paris and Baltimore respectively.

Up to this point, the organization of the workshops had been virtually nonexistent; the chairman called upon other interested persons to make plans for the workshops. But in the April 1989 meeting of the COMPUMAG International Steering Committee, the committee agreed to take TEAM under its wing, and appointed a chairman and two vice-chairmen (one each from Asia, Europe, and North America).

The international workshop, held immediately after COMPUMAG-Tokyo at Okayama University together with the International Symposium on 3-D Electromagnetic Field Analysis, was larger than any other workshop before or after, with 243 participants from 19 countries. Individual presentations and summaries of the solutions for the six active problems, together with seminar presentations and suggestions for new problems, filled the agenda. Only during lunch and dinner meetings could we plan

for future workshops. Again the summaries were published as a special issue of COMPEL; the proceedings of the workshop and seminar appeared as a supplement to COMPEL.

ROUND 3

At the first regional workshop, in Oxford following Intermag in Brighton, some of the plans made in Okayama were further developed. A TEAM planning board, selected from chairmen of earlier workshops, was chosen to help the chairman and vice-chairmen. Policies about closed problems were also adopted. At Oxford, and indeed at all subsequent workshops, there were numerous solutions to Problem 13, the first magnetostatics problem. High-frequency problems were also talked about at Oxford. The second regional workshop was held in Graz, but I did not attend.

The third workshop, in Toronto after the Computational Electromagnetic Fields Conference, was the first joint workshop of TEAM and ACES (Applied Computational Electromagnetics Society). ACES is mostly concerned with high frequency electromagnetics, and their problems are mainly on high frequencies; some specifically high frequency problems have also been adopted by TEAM. Also at Toronto, there was extended discussion of Problem 13. The fourth workshop was in Sendai, Japan.

The international workshop was in Sorrento, immediately after COMPUMAG-Sorrento. Again some problems were closed, new problems were chosen, a new chairman and co-chairmen were appointed, and another round of workshops was planned.

ROUND 4

Workshops were held in Grenoble and Claremont, California. Claremont was in fact as well as in principle a joint TEAM/ACES Workshop.

Here today, we are finally accomplishing the long-held dream of having a TEAM Workshop in China. Future workshops of this round will be held in Sapporo, Japan and on the ferry between Stockholm and Helsinki. The international workshop will be held just after COMPUMAG-Miami.

SUCSESSES OF THE TEAM WORKSHOPS

In the original planning meeting for TEAM, the goals for the workshops were stated as: "The ultimate goal is to show the effectiveness of numerical techniques and associated computer codes in solving electromagnetic field problems, and to gain confidence in their predictions. The workshops should also provide cooperation between workers, leading to an interchange of ideas." It is useful, perhaps, to list at

this point some of the benefits that have come from the TEAM Workshops.

1. Numerical techniques are more effective and we have more confidence in their predictions than when the goals were defined. Although it is impossible to say how much of the credit the TEAM Workshops should claim, certainly the workshops have brought together workers from different continents and different areas of application and have made them more of a community. There are smaller examples of such community-building also. It was in the workshops that people in our field from different branches of a gigantic Japanese corporation first met and began working together. At the opposite ends of the earth, groups began working together who were known all over the world for their inability to cooperate.
2. Problems that have been well studied and are well understood, including the retired problems, are available for anyone who needs an example for a new code.
3. At every conference we see TEAM problems being used as examples in presented papers. For many audiences, the problem may be identified only by a phrase (e.g., "the Bath cube"), and need not be further explained.
4. Solving the problems has disclosed "bugs" in some widely-used software, which were subsequently corrected.
5. Although we were considered naive to expect this to happen, some developers have changed and extended their codes so they could solve the problems.
6. Some groups (the Okayama and Graz groups come to mind) have used different methods to solve the same problem. This process has given us our best opportunity to compare methods and find which method is best for which kind of problems.
7. Workshops that by chance concentrate on one problem have given us new and practical understanding of general topics in electromagnetic computation and theory. Examples are Problem 13 and comparison of B type and H type methods (Toronto workshop) and Problem 6 and energy considerations for an extended field (Atlanta workshop).

NEW DIRECTIONS

At many of the TEAM Workshops, new problems are suggested. Today Cheng Zhiguang of the Baoding Transformer Works has suggested a problem related to eddy currents in a transformer casing or other equipment. Let me mention some classes of problems that might be useful, based on discussions at earlier workshops.

1. **FORCE PROBLEMS.** In addition to the two classical methods of computing forces, virtual work and the Maxwell stress tensor, there are several other variations, as described in Prof. Nakata's talk at the ICEF. Despite a session on this topic at COMPUMAG-Graz and discussions at many meeting before and since, there is no clear-cut way of knowing when one or another is best. The problem described today by Prof. Takahashi (and later approved as a TEAM problem) will be helpful, but other problems can also be considered.
2. **HYSTERESIS.** When I hear talks on the Preisach model and on phenomenological models of hysteresis, I can hardly believe they are describing the same topic. I have been trying to encourage people to suggest TEAM problems on hysteresis for several years, but so far without success.
3. **CURRENT CROSSING INTERFACE.** Different methods for computing eddy currents should have different degrees of success with problems in which the current crosses an interface between regions with different finite conductivities. Suitable problems have been suggested to investigate this, in particular the four-segment torus proposed by Z. Ren and A. Razek at the Okayama workshop, but none with an experimental or analytical solution, as required for a TEAM problem. Experimentally the difficulty is providing a very low resistance joint where the two materials are joined. (The suggestion this week that one of the materials be liquid is promising, but an alloy or amalgam of higher resistance may form at the interface.) No one has suggested an analytical solution to the Ren and Razek problem, or a variation. Perhaps a two-component cylinder or sphere, with core and mantle of different conductivities, located in a non-linear external field would provide an analytical problem.
4. **HIGH PRECISION FIELDS.** MRI and accelerator magnets require a field with spatial distribution known to high precision. Perhaps the measured sextupole magnets for the storage ring of the Advanced Photon

Source would be a suitable TEAM problem, particularly since ideally it would benefit from using third-order finite elements.

5. MAGNETIC LEVITATION. TEAM Problem 9, coil moving in a metal tube, is a moving conductor problem, but perhaps one more directly related to a magnetic levitation geometry would also be useful.

6. RECORDING HEADS. As magnetic recording systems become smaller and smaller, computation of recording heads continues to be important. Perhaps a manufacturer or someone else could provide measurements to be used in such a problem.

7. INVERSE PROBLEMS AND OPTIMIZATION. This is a hot topic at every conference. As one suggestion for a problem, Klaus Halbach of the Lawrence Livermore Laboratory recently called my attention to the problem of designing a dipole accelerator magnet to give a highly uniform field both at low field levels and at higher excitation where there is saturation. But including an inverse problem in TEAM would require some changes from the way problems are normally defined. To be convincing in applying inverse methods to a problem requires a certain innocence in choosing a starting point. A great deal more thought is needed before such a TEAM problem can be defined.

CONCLUSIONS

It has been a great pleasure to be here today at the first TEAM Workshop to be held in China. I will never forget the beauty and kindness I have found here.

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APPENDIX

PROCEEDINGS OF EARLIER TEAM WORKSHOPS

I list here the chairmen and proceedings of the TEAM Workshops to date. Some of these proceedings may no longer be available. Others (certainly the ones published in COMPEL) require payment. For some of them, I do not have the title and number of the proceedings. Note that the name TEAM was adopted for the workshops in Tokyo in April 1987.

RUTHERFORD APPLETON LABORATORY, 27 MARCH 1986. C. R. I. Emson (now at Vector Fields Ltd., Oxford, UK), chairman and editor, "Electromagnetic Workshop," RAL-86-049.

ARGONNE NATIONAL LABORATORY, 23-24 JUNE 1986. L. R. Turner, chairman and editor, "Proceedings of the Regional Electromagnetic Workshop at Argonne National Laboratory," ANL/FPP/TM-210.

TOKYO ELECTRIC POWER COMPANY, 20-21 OCTOBER 1986. K. Miya (University of Tokyo) and T. Nakata (Okayama University), chairmen and editors, "The International Workshop for Eddy Current Code Comparison."

ECOLE CENTRALE LYON, 18-19 NOVEMBER 1986. Alain Nicolas, chairman and editor.

GEORGIA INSTITUTE OF TECHNOLOGY, 12-13 JANUARY 1987. K. R. Davey, chairman and editor, "5th International Eddy Current Workshop," GTFR71.

TECHNICAL UNIVERSITY OF GRAZ, 20-21 AUGUST 1987. L. R. Turner, chairman and guest editor, COMPEL, Special Issue: Papers on benchmark problems for the validation of eddy current computer codes. Volume 7, Numbers 1 & 2, March/June 1988.

UNIVERSITY OF BRITISH COLUMBIA, 18-19 JULY 1988. L. R. Turner, chairman and editor, "Proceedings of the Vancouver TEAM Workshop at the University of British Columbia," ANL/FPP/TM-230.

CAPRI, ITALY, 5-7 OCTOBER 1988. R. Albanese (University of Salerno), chairman. R. Albanese, E. Coccorese, Y. Crutzen, R. Martone, G. Rubinacci, editors, "Electromagnetic Workshop and Meeting on the

Industrial Applications of the Eddy Current Codes," Commission of the European Communities Joint Research Centre, EUR 12124 EN.

ELECTRICITE DE FRANCE, PARIS, 20-21 MARCH 1989. J. C. Verite, chairman. J. C. Verite, A Bossavit, J. Cahouet, Y. Cretzen, editors, "TEAM Workshop and Meeting on the Applications of Eddy-Currents Computations," Commission of the European Communities Joint Research Centre, EUR 12256 EN.

JOHNS HOPKINS UNIVERSITY, BALTIMORE, 3-4 APRIL 1989. N. Ida (University of Akron), chairman and editor, "Proceedings of the Baltimore TEAM Workshop at the Johns Hopkins University," University of Akron.

OKAYAMA UNIVERSITY, 11-13 SEPTEMBER 1989. T. Nakata, chairman and editor, "3-D Electromagnetic Field Analysis," COMPEL, Volume 9, Supplement A, 1990. Also L. R. Turner, guest editor, COMPEL, Special Issue: Papers on benchmark problems for the validation of eddy current computer codes. Volume 9, Number 3, September 1990.

OXFORD, ENGLAND, 23-25 APRIL 1990. N. J. Diserens (now at AECL Research, Chalk River, Ontario), C.R.I.Emson (Vector Fields, Ltd.), D. Rodger (University of Bath), chairmen. Y. Crutzen, N. J. Diserens, E. R. I. Emson, D. Rodger, editors, "European TEAM Workshop and International Seminar on Electromagnetic Field Analysis," Commission of the European Communities Joint Research Centre, EUR 12988 EN.

GRAZ UNIVERSITY OF TECHNOLOGY, OCTOBER 1990. Kurt Richter, Wolfgang Rucker and Oszkar Biro, chairmen.

ONTARIO HYDRO, TORONTO, 25-26 OCTOBER 1990. H. Sabbagh (Sabbagh Associates, Bloomington, Indiana), chairman. L. R. Turner, editor, "Proceedings of the Toronto TEAM/ACES Workshop at Ontario Hydro," ANL/FPP/TM-254.

TOHOKU UNIVERSITY, SENDAI, JAPAN, 31 JANUARY-1 FEBRUARY, 1991. T. Takagi, chairman and editor, "Proceedings of Asian TEAM Workshop and International Seminar on Computational Applied Electromagnetics," IFS-TM001.

SORRENTO, ITALY, 12-13 JULY 1991. E. Coccoresse (University of Reggio Calabria), chairman. R. Albanese, E. Coccoresse, Y. Crutzen, P. Molfino, editors, "Third International TEAM Workshop," Commission of the European Communities Joint Research Centre, EUR 14173 EN. Also,

Giorgio Molinari, guest editor, COMPEL, Special Issue: Benchmark problems for the validation of eddy current computer codes. Volume 11, Number 3, September 1992.

GRENOBLE, FRANCE, 16-19 MARCH 1992. A. Nicolas, chairman.

CLAREMONT, CALIFORNIA, 6-7 AUGUST 1992. H. Sabbagh, chairman. Proceedings to be published by ACES.

XIN'AN RIVER HYDRO POWER STATION, 1000 ISLAND LAKE, CHINA, 18-19 OCTOBER 1992. Ni Guangzheng, chairman and editor.

HOKKAIDO UNIVERSITY, SAPPORO, JAPAN, 29-30 JANUARY 1993. T. Honma, chairman.

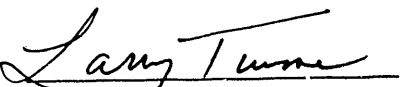
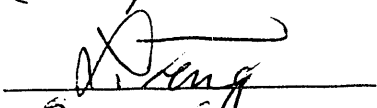
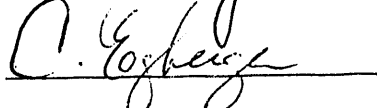
STOCKHOLM/HELSINKI FERRY, 17-18 APRIL 1993. L. Kettunen (Tampere University of Technology), chairman.

MIAMI, FLORIDA, 5-6 NOVEMBER 1993. Contact O. Mohammed, Florida International University, for information.

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